Final Report, Joint Fire Sciences Program Project No. 03-2-3-08

Title: Pre-fire condition, fire severity, and post-fire effects in the Hayman Burn, Colorado

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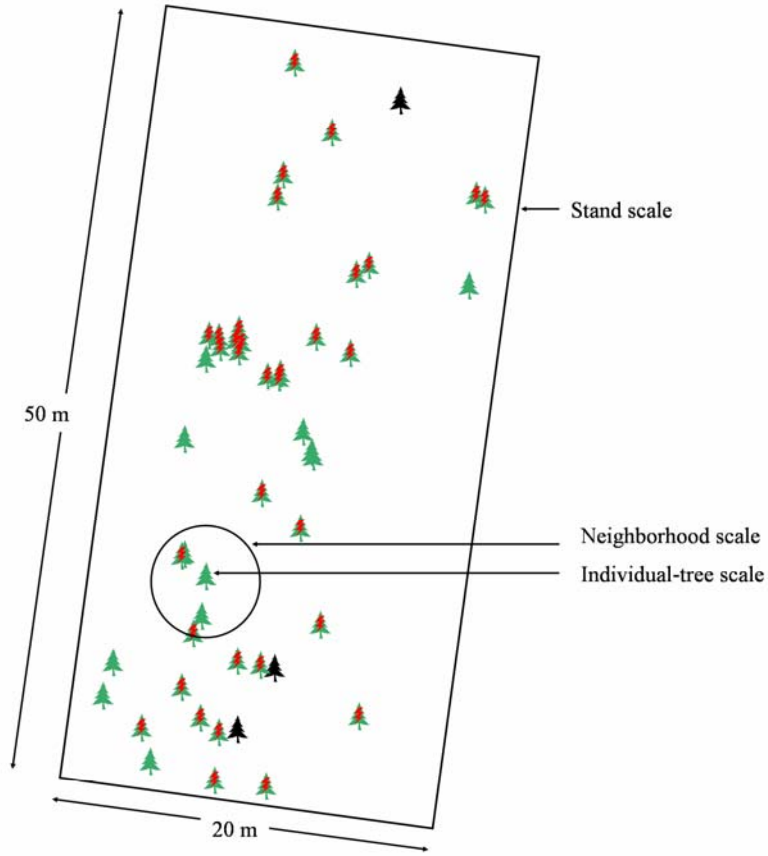
This report for JFSP Project 03-2-3-08 summarizes findings of a research project designed to take advantage of several types of pre-fire plot data resampled after the 2002 Hayman fire. The project abstract from the original proposal is reproduced here as an outline of the work.

> Project Abstract**:** "Ongoing research within the 2002 Hayman burn provides an excellent framework for comparing effects of the Hayman burn to pre-fire forest conditions. Two pre-fire data sets support the proposed research. One characterizes historical landscape structure and key regulating processes and includes plot-level measurements of forest overstory structure, understory species composition, fuels, and fire history. The second dataset is pre-treatment monitoring data collected as part of the Upper South Platte Restoration Project, which includes forest overstory and understory plant data, surface fuels, and habitat monitoring for several species of concern. All of these plots burned with varying intensity. Our primary objectives focus on re-sampling our pre-burn plots near Cheesman Lake and Saloon Gulch to (1) evaluate the effects of burn severity, pre-fire stand characteristics, and topography on tree survivorship; (2) determine the effects of burn severity and pre-fire composition on post-fire understory species composition; (3) examine the effects of pre-fire fuels and vegetation structure on patterns of burn severity, and (4) investigate the effects of burn-severity on habitat for species of concern. The proposed study augments collaborative projects, including validation of relationships in the FFE of the Central Rockies FVS variant, validation of pre-fire fuel reconstructions derived from post-fire surveys, and modeling fire behavior with mesoscale weather data for the study area."

In the following sections, findings are reported for each of the four primary objectives of this project. The delivery crosswalk information is summarized in two places, one for the first two objectives, and one for the second two.

Objective A. Effects of burn severity, pre-fire stand characteristics, and topography on tree survivorship

Research work for this objective took the form of evaluating how factors at three spatial scales influenced the probability of fire-caused mortality for an individual tree. The three scales investigated here were the individual-tree scale, the neighborhood scale, and the stand scale. The schematic diagram below illustrates the relationship between these three scales. Data were collected in 25 0.1 ha plots at Turkey Creek, a 4-km^2 study area established in 1996. Pre-fire data were collected in 1996-7, and post-fire data were collected in 2003 (one year after the Hayman fire). This Joint Fire Science Program grant funded the post-fire data collection for this study.



A schematic diagram illustrating the plot layout and the three nested scales of data collection. Black trees are trees that were dead before the fire (standing snags). Green trees are trees that were alive before the fire. Trees with red lightning bolts are trees that died in the fire.

Individual-tree variables described the tree's morphology. Variables analyzed included (1) diameter at breast height (DBH); (2) height; (3) height to live crown; and (4) species. Neighborhood scale variables described the conditions within two-meter radius of the tree's stem, creating a neighborhood 12.6 m^2 in size. Two meters was chosen as the neighborhood radius to maximize the number of neighborhoods analyzed while minimizing the number of 'empty' neighborhoods. Two meters is also the approximate radius of an average tree crown at our study site. Neighborhood scale variables included (1) the pre-fire tree density in the neighborhood; (2) the basal area of the neighborhood; and (3) the pre-fire density of suppressed trees in the neighborhood. Finally, stand scale variables described the broader stand structure that the individual tree was placed in, and was represented by the entire 0.1 ha plot. Stand scale variables used in this study included (1) topographic position; (2) average percent slope; (3) history of prescribed burning (yes or no); (4) pre-fire tree density in the plot; (5) pre-fire basal area of the plot; and (6) pre-fire density of suppressed trees in the plot.

Results of this research indicate that tree mortality due to wildfire is related to factors at multiple spatial scales. Variables that describe tree morphology, the local neighborhood structure, and the broader stand structure were all meaningful in describing and predicting tree mortality. Logistic modeling showed that DBH and species were significant morphological variables, and they explained 24% of the variability in individual tree mortality. The only significant neighborhood-scale variable was the number of trees per neighborhood, which explained 6% of the variability. Both basal area and the pre-fire density of suppressed trees were significant stand-scale variables, and together they explained 19% of the variability in individual tree mortality. While these R^2 values indicated that our models may not be very accurate predictive tools, they also indicated that there is indeed a relationship between tree mortality and factors at each of these three spatial scales.

Objective B. Effects of burn severity and pre-fire composition on post-fire understory species composition

Research work for this objective looked at changes in the understory plant community as a result of fire. As in Objective 1A, data were collected in the 25 Turkey Creek plots, with pre-fire data collected in 1996-7, and post-fire data collected in 2003. This Joint Fire Science Program grant funded the post-fire data collection for this study.

Across the entire study area, pre-fire understory composition exhibited the strongest influence over the post-fire understory plant community. Burn severity was less important at this scale, since the study area burned with mixed severity (and some areas along the river did not burn at all). 169 individual species were identified before the fire, and 158 were identified after, with 116 species in common between the two years (Jaccard's Index=0.55). Many of the unique species in the pre-fire or post-fire plant communities were found in only a handful of plots. When the pre-fire and post-fire species were classified into functional groups, the plant community also appeared relatively unchanged. Each species was classified into three different functional groups: growth form (forb, graminoid, shrub/subshrub, tree, or vine); nativity to Colorado (native or exotic); and life span (annual/biennial/short-lived perennial or long-lived perennial). When the species were classified by growth form, the pre-fire and post-fire communities were quite similar. Before the fire, there were 112 forbs species, 27 graminoid species, 23 shrub/ subshrub species, 5 tree species, and 2 vine species. After the fire, there were 109 forb species, 21 graminoid species, 17 shrub/subshrub species, 6 trees species and 3 vine species. There was a slight decline in the number of natives, and a slight increase in the number of exotics after the fire. Before the fire, 156 of the species were native and 13 were exotic. After the fire, 140 of the species were native, and 18 were exotic. One of the post-fire exotics (*Tritosecale rimpaui*) was intentionally seeded for soil stabilization. The number of short-lived plant species increased slightly after the fire. Before the fire, 25 of the species were annuals, biennials, or very short-lived perennials. After the fire, 33 of the species were annuals, biennials, or very short-lived perennials. Many of the new short-lived species were also exotic (thus the increase in exotics and in short-lived species is correlated).

Changes in plot-level biodiversity and percent cover were related to both pre-fire understory composition as well as burn severity. The focus of this analysis was on native versus exotic biodiversity and cover, since managers and others are especially concerned about the potential for increased exotics due to fire and fire suppression activities. When all plots were analyzed together (that is, not separated by burn severity), we found that native richness and percent cover per plot were not significantly different before and after the fire. However, exotic richness and percent cover per plot was significantly higher after the fire than before. Analyzing the data by burn severity class provided some insight into the role of fire in shaping plant communities. Lightly-burned plots had significantly higher native understory richness and cover after the fire than before the fire. However, moderately-burned and intensely-burned plots did not exhibit a change in native richness or cover after the fire. In contrast, exotic richness and cover were significantly higher for all burn severity classes after the fire.

Delivery crosswalk table (listed in chronological order of completion

Proposed	Delivered	Status
Collaborative work	Data provided to Phil Omi and Erik Martinson in support of their JFSP project on fire, fuel treatments, and invasive species	January 2004
Collaborative work	Data provided to the FVS-FFE modeling group to help validate their model.	April 2004
Talk	Fornwalt, P.J. and M.R. Kaufmann. 2004. 'Effects of the 2002 Hayman Fire, Colorado, on understory species composition.' 89th Annual Meeting of the Ecological Society of America. Portland, OR.	August 2004
Publication	Fornwalt, P.J., M.R. Kaufmann, W.H. Romme, and L.S. Huckaby. 'Why does fire kill some trees and not others? Correlating post-fire tree mortality with information from multiple spatial scales.' Manuscript in preparation for the International Journal of Wildland Fire.	In progress
Publication	Fornwalt, P.J., M.R. Kaufmann, W.H. Romme, and L.S. Huckaby. 'Pre-fire conditions and burn severity influence plant community composition one year after fire.' Manuscript in preparation for the International Journal of Wildland Fire.	In progress
Talk	Fornwalt, P.J. 2006. 'Non-native plant species, restoration, and fire in ponderosa pine forests of the Colorado Front Range.' Third International Fire Ecology and Management Congress. San Diego, CA.	Planned November 2006

Additional deliverables (not originally proposed in grant)

Media Interview	Ashes to asters: life floods back to the Hayman Fire area. Story by Dave Phillips of the Colorado Springs Gazette. August 26, 2005.	August 2005
Poster	Fornwalt, P.J. 2006. 'The effects of fire, postfire rehabilitation, and thinning on understory plant communities in ponderosa pine/ Douglas-fir forests.' Manitou Experimental Forest Open House. Woodland Park, CO.	August 2006

Objective C. Effects of pre-fire fuels and vegetation structure on patterns of burn severity.

We were only able to relocate 10 of the pre-burn samples at Saloon Gulch due to inaccuracy of GPS readings, post-fire loss of permanent plot markers, and the unfamiliarity of the field crew with the pre-fire plot locations. Consequently, we conducted the analysis of burn severity patterns based on after-only plots because they were randomly distributed across a large portion of the Hayman burn (59915 ha) and included the full range of burn severities. We compared these burn severity patterns with two other large fires in Colorado (burned in 2000): the Hi Meadows fire (4422 ha) and the Bobcat Gulch fire (3059 ha); all three burns occurred in areas classified as a mixed-severity fire regime. The distribution of area burned across the burn severity gradient was similar between the Hayman burn and the smaller burns, and was fairly evenly distributed across all burn severities. Due to the much smaller size of the 2000 burns, however, the size of crown fire patches and distance to live trees was much greater at the Hayman burn. Despite the differences in spatial heterogeneity among the burns, avian response patterns were fairly consistent across these burns (see also Objective D).

Objective D. Effects of burn-severity patterns on habitat for wildlife species of concern.

Our original objective was to evaluate how burn-severity patterns can affect several species of concern. Once we initiated the modeling study it became clear that we would be unable to achieve our objectives as originally stated for several reasons. First, a concurrent study of before-after analysis at the Cerro Grande fire found that due to low sample sizes and high spatiotemporal variation, there was very low power to detect difference between pre- and post-fire avifauna; greater statistical power was obtained with after-only gradient analysis and larger samples sizes from random post-fire plots (Kotliar et al. *in press*, Ecological Applications). At the Hayman burn, our pre-burn sample sizes were relatively low, thus there was not enough power to warrant pre-post comparisons. Instead, we employed the after-only gradient analysis. Second, after consulting with colleagues involved with Mexican spotted owl habitat modeling in Arizona, it was evident that we would be unable to develop appropriate models due to the low number of breeding birds in the Hayman burn area, coupled with the complexity of habitat models and funding limitations. Third, the location of long-term transects monitoring the Pawnee montane skipper did not coincide with much of the Hayman burn area, and those within the burn perimeter only occurred in low- and moderate-severity burns. Finally, restructuring of USGS funding reduced the scope of work for the companion project on avifauna at the Hayman burn. Consequently, we restricted our study to a single species of concern, the American three-toed woodpecker (*Picoides dorsalis*) rather than address all species originally proposed.

We selected the three-toed woodpecker as a focal species for several reasons. First, it is a well-known associate of severely burned forests. Second, the staff at the Pike National Forest has a strong interest in this species. In particular, the effects of post-fire salvage operations on this species is a critical information need, but our understanding of their use of burns is quite limited. Third, we had a unique opportunity to study this rare species due to the large number of birds observed at the Hayman burn; in total, we observed 90 individuals across two years, which is a much larger sample size than any other published study of three-toed woodpeckers.

The USGS portion of this work on the woodpeckers was conducted at broad scales relating to territory locations of the woodpeckers and other species. The funds provided by JFSP allowed us to focus on the major food resources of the three-toed woodpeckers (wood-boring and bark beetles) and to quantify how both burn severity and beetle occurrence influenced foraging decisions by the woodpeckers.

Three-toed Woodpeckers:
Three-toed woodpeckers respond to burn severity across a range of scales. At the largest scales (400-ha areas), three-toed woodpeckers settled into areas that had both live and dead trees present, but did not establish territories in large contiguous areas of dead or live trees. Thus, three-toed woodpeckers appear to prefer mixed-severity burns that contained crown fire patches. At finer scales (36-ha), burn severity influenced foraging patch selection. Three-toed woodpeckers were observed foraging in patches of trees with a greater proportion of intermediately burned trees (i.e., scorched, live trees) compared to the surrounding landscape. Within patches, tree size and beetle occupancy influenced tree selection and giving up times during foraging bouts. Although, three-toed woodpeckers readily used severely burned forests, the spatial configuration of severely burned patches can affect their distribution across burns. Larger crown fires that result in extensive areas without any live trees (e.g., > 500 m to live trees) may reduce suitability of severe burns for three-toed woodpeckers. However, spatial heterogeneity within severely burned areas (e.g., remnant live trees along riparian corridors, high edge:interior ratio of crown fire patches) can increase suitability of very large crown fires for three-toed woodpeckers.

Avifaunal Response Patterns:
In a previous study of wildland fire at the Cerro Grande burn in New Mexico, avian response patterns across a burn severity gradient were classified into six response classes in response to increasing burn severity: (1) large significant declines, (2) weak, but significant declines, (3) no significant density changes, (4) peak densities in low- or moderate-severity patches, (5) weak, but significant increases, and (6) large significant increases. We compared the responses of species observed at the Hayman burn with that observed at Cerro Grande. We also compared avifaunal responses at the Hi Meadow and Bobcat Gulch burn.

As with the Cerro Grande burn, a broad spectrum of responses to burn severity was observed with the Hayman fire. Species with strong significant negative or positive responses to burns (response classes 1 and 6) were highly consistent across burns. Thus the larger size of crown fire patches at the Hayman burn did not deter use by species with strong positive responses to burns. A few species showing weak or non-significant changes in density across the burn severity gradient at Cerro Grande (response class 2 and 3) showed greater, and significant, declines in density at the highest burn severities at the Hayman burn. The few species that differed across burns in their apparent tolerance or avoidance of high-severity areas reflects the much larger size of these areas at the Hayman burn.

Delivery crosswalk table

Proposed	Delivered	Status
Publication	Reynolds, E.W. 2004. American three-toed woodpecker response to spatial patterns of burn severity and prey availability. Master of Science. San Diego State University, CA	Done
Publication	Reynolds, E.W., N.B. Kotliar, D.H. Deutschman. Three-toed woodpecker response to spatial patterns of burn severity and prey availability. Manuscript in preparation for Condor	In progress
Publication	Kotliar, N.B. Avifaunal responses to fire in the southern Rocky Mountains: the role of burn severity and spatial heterogeneity. Manuscript in preparation for Ecology	In progress
Publication	Kotliar, N.B. and S. Haire. Post-fire spatial heterogeneity among fire regimes in the southern Rocky Mountains. Manuscript in preparation for Landscape Ecology	In progress
Talk	Kotliar, N.B. 2006. Avifaunal responses to fire along a burn severity gradient in montane forests of the southern Rocky Mountains. Western Field Ornithologists Annual Meeting Boulder, CO. September 2006	Planned for September 2006
Talk	Kotliar, N.B. Avifaunal responses to fire along a burn severity gradient in montane and subalpine forests of the Rocky Mountains. 2006. Third International Fire Ecology and Management Congress. San Diego, CA. November 2006.	Planned for November 2006
Talk	Kotliar, N.B. 2006. Rocky Mountain National Park Research Conference. Avifaunal response to fire along a burn severity gradient in forests of the Rocky Mountains, Rocky Mountain National Park Science Conference. Estes Park, CO	Done
Talk	Kotliar, N.B. 2005. Effects of Fire on Avian Communities. Colorado Chapter of the Wildlife Society. Colorado Springs, CO. January 2005	Done
Talk	Reynolds, E. W. 2005. The response of Three-toed Woodpeckers to spatial patterns of burn severity at the Hayman burn. Colorado Chapter of the Wildlife Society. Colorado Springs, CO. January 2005	Done